LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-647695

Letter Report on 500 nA Pulsed Current from Field Ionization Source

J. L. Ellsworth

December 12, 2013

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

LLNL-TR-647695

Monday, December 9, 2013

Dr. Jennifer L. Ellsworth
Lawrence Livermore National Laboratory
7000 East Avenue, L-153
Livermore, CA 94550

Dr. David Beach
Dr. Arden Dougan
National Nuclear Security Administration
Washington, DC

Dear Dr. Beach and Dr. Dougan,

We recently produced a milestone 500 nA of pulsed current using 40 Ir field ionizer electrodes in our ion source for the LL11-PyroNeuSource-PD03 project. We have previously demonstrated DC currents on the order of 100 nA using 10 field ionizer electrodes in the same ion source and have also demonstrated sustained neutron yields > $2 \bullet 10^4$ DD n/s using this ion source and deuterated titanium targets. We have also demonstrated pulsed neutron yields of $1 \bullet 10^4$ DD n/s using the pulsed ion source with 10 field ionizer electrodes. We expect that 500 nA of current will produce neutron yields of $1 \bullet 10^5$ DD n/s (and $1 \bullet 10^7$ DT n/s).

Figure 1 shows a schematic and photograph of the ion source including the ground grid and magnetic aperture. The electrodes are mounted on pins and etched to 100 nm tip radius. They are then installed in sockets in the circuit board and aligned by hand. Each electrode is current limited by a 1 GΩ resistor so that if one tip is damaged, the other tips won't be affected.

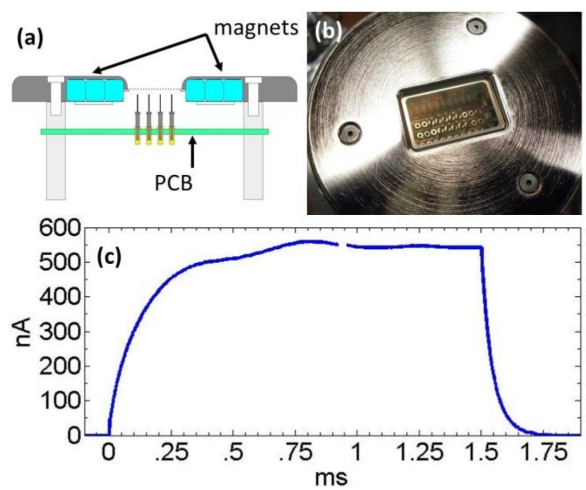

Figure 1: (a) Schematic of the ion source. (b) Photograph of the ion source (top view). (c) Demonstration of 500 nA current from the pulsed ion source. This trace is an average of 240 current traces. The current was generated using 40 electrodes biased to 19.5 kV peak voltage and 20 mTorr D_2 fill pressure.

The 40-tip ion source produced 500 nA using a 19.5 kV voltage pulse and 20 mTorr D_2 gas fill pressure. The current trace shown in figure 1 is an average of 240 pulses. The ion source current was measured by a collector plate through a buffer amplifier circuit with a passive current to voltage converter. A systematic exponential RC decay time of 60 µs was measured for the amplifier and collector plate. For 500 nA signal levels, this corresponds to a 90%-10% fall time of ~ 100 µs. We measure a fall time of 100 µs for the ion current, which is mostly due to the electronics.

The rise time of the current is about 300 µs. We believe this rise time is due to the RC time of the 1 GΩ resistors with the stray capacitance in the system. This is noticeable in the rise times, but not the fall

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

times because the current falls exponentially with voltage. We expect that reducing the resistance to 200 MΩ will drop the RC time a sufficient amount to reduce the rise time to less than 100 µs.

A custom high voltage pulser was designed and built for the ion source as part of this experiment. The pulser box is capable of producing 25 kV pulses with durations as short as 500 µs. The high voltage power supplies and switch inside the box are battery powered. The box is remote controlled by low voltage (<10 VDC) signals. Bench testing of the pulser box demonstrated that the box is capable of producing high voltage 20 kV pulses with rise and fall times of < 10 µs. The pulser box is mounted directly to the high voltage vacuum feedthrough that the ion source is connected to in order to minimize the capacitance of the load. Most of the power is used for air cooling of the solid state high voltage switch and most of the size and weight of the pulser comes from the high voltage switch. We are actively investigating alternate, more compact options for low current, high voltage switches.

The true test of the rise and fall times will be the rise and fall time of the neutrons. Experiments are planned to use plastic scintillators with pulse counting hardware to measure the rise and fall time of the neutrons produced during integrated tests.

In conclusion, we have produced the milestone pulsed current of 500 nA using 40 electrochemically etched iridium tips in a field ionization source. The pulsed current output is repeatable and scales as expected with gas fill pressure and bias voltage. We expect these current will be sufficient to produce neutron yields of $1 \bullet 10^7$ DT n/s.

Sincerely,

Jennifer Ellsworth

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC